



# SPECIFICATION

[Electronic Version 1.2.8]

## More Uniform Electroluminescent Displays

### Detailed Description

- [0001] This invention is concerned with electroluminescent displays, and relates in particular to improving the uniformity and visibility of such displays.
- [0002] Certain materials are electroluminescent – that is, they emit light, and so glow, when an electric field is generated across them. The first known electroluminescent materials were inorganic particulate substances such as zinc sulphide, while more recently-found electroluminescent materials include a number of plastics – synthetic organic polymeric substances – known as light-emitting polymers (LEPs). Inorganic particulates, in a doped and encapsulated form, are still in use, particularly when mixed into a binder and applied to a substrate surface as a relatively thick layer; LEPs can be used both as particulate materials in a binder matrix or, which some advantages, on their own as a relatively thin continuous film.
- [0003] This electroluminescent effect has been used in the construction of displays, in which a large area of an electroluminescent material – generally referred to in this context as a phosphor – is provided to form a backlight which can be seen through a mask that defines whatever characters the display is to show.
- [0004] Such a backlight commonly consists of, from front (the side from which it is to be viewed) to back:
- [0005] a relatively thick protective electrically-insulating transparent front layer known as the substrate and made usually of a glass or a plastic such as polyethylene terephthalate (PET);
- [0006] over the entire rear face of the substrate, a very thin transparent electrically-conductive film made from a material such as indium tin oxide (ITO), this forming one electrode – the front electrode – of the backlight;
- [0007] covering the rear face of the front electrode, a relatively thin layer of electroluminescent/phosphor material (usually a particulate phosphor within a binder matrix);

- [0008] over the rear face of the phosphor layer, a relatively thin electrically-insulating layer of a material – usually a ceramic – having a relatively high dielectric constant (relative permittivity) of around 50;
- [0009] covering the entire rear face of the phosphor layer, a continuous electrically-conductive film, usually opaque (and typically carbon or silver), forming the other electrode – the back electrode – of the backlight.
- [0010] In addition, the back electrode layer, which is quite delicate, is covered with a protective film (usually another, similar, ceramic layer) to prevent the layer being damaged by contact with whatever device components – electronic circuitry, for example – might be mounted behind the display.
- [0011] Each of the various layers is conveniently screen-printed into place (apart from the ITO front electrode, which is usually sputtered onto the substrate) in the normal way, through masks that define the shape, size and position of the layer components, using suitable pastes that are subsequently dried, set or cured, commonly by heat or ultraviolet light, as appropriate, prior to the next layer being applied. And in the context of electroluminescent displays, the expressions "relatively thick" and "relatively thin" mean thicknesses in the ranges, respectively, of 30 to 300 micrometres, usually around 100 micrometres, and less than 50 micrometres, and most usually 25 micrometers or less.
- [0012] In a display, such a backlight is positioned behind a mask that defines whatever characters the display is to show. Unfortunately, to form a truly effective, easy-to-read display the background uniformity of the display must be well controlled so as not to distract the eye of the Viewer from the information that it is intended to reveal. To date this has not satisfactorily been achieved for electroluminescent displays.
- [0013] As intimated above, the majority of electroluminescent displays exploit the uniform illumination properties of the electroluminescent principle as a backlight, enabling graphics characters to be formed through the use of cut out overlays that allow the light to shine through specific apertures. Characters formed in this way using particulate phosphors tend to be less than sharp. Moreover, such a display is an "all or nothing" display; when the backlight is "on", all the characters are illuminated, while when it is "off" none of them are.
- [0014] It was then realised, however, that much clearer, crisper displays, with individually-activatable characters, could be constructed by "reversing" the normal structure of backlight with masking overlays. More specifically, it was found that if the phosphor layer were associated on at least one side (and particularly at the rear) with an array of individual appropriately-shaped electrodes instead of a continuous electrode then the mask could be done away with completely, for the phosphor could be

inherently activatable in the forms of the discrete shapes desired – for example, an ikon, an alphanumeric character, or a pattern of independently-switchable segments that by their arrangement provide reconfigurable information – so there could be made a display that had the desired sharpness.

[0015] The thus-formed displays were indeed a considerable advantage over the previous, mask-utilising, ones, but they still suffered from a number of drawbacks. One such arose directly from the use of individual appropriately-shaped back electrodes instead of a continuous electrode; whereas with a continuous back electrode extending effectively from edge to edge of the display an activating voltage could be supplied by a lead to a contact at the very edge of the display, which could easily be hidden from sight, individual back electrodes required leads, formed as conductive tracks laid onto the dielectric layer carrying the electrodes, some of which track leads necessarily crossed over the main area of the display. And since each track lead, even though extremely narrow, acted as an electrode in its own right, the phosphor was activated not only by each individual shaped electrode but also by the lead to that electrode, giving rise to a faint, but distracting (and possibly confusing), additional source of illumination, making each ikon or character of the display look as though it had a tail.

[0016] Various attempts have been made to deal with this problem, and one of the more successful to date is not to form the lead tracks directly on the dielectric layer carrying the back electrodes, as is usual, but instead to space the tracks further from the electroluminescent material layer by placing an additional insulating layer between the tracks and the dielectric layer carrying the electrodes, so as to reduce the field produced by the tracks, and so minimize the unwanted activation and illumination effect of the underlying phosphor. However, each track lead still acts as an electrode, and so still gives rise to a faint, albeit now much fainter, source of illumination, so that each ikon or character of the display still looks as though it has a tail.

[0017] This problem of track-derived tails is one of those that has been dealt with by the invention of a previous Patent Application. Thus, in the Specification of our co-pending British Patent Application No: 0308598.0 it is proposed that the - electroluminescent material itself be formed into discrete areas each tightly matching in shape and size the relevant individual shaped back electrode. This works well, but has an unfortunate side effect: although a display made using a shaped-area back electrode and a correspondingly shaped-area phosphor layer is sharp and crisp, and does away with the requirement for an image-defining mask, the thus-formed display suffers a drawback which derives from the very "removal" of the mask and the concomitant shaping of the electroluminescent material. The problem is that even when the electroluminescent material – the phosphor – is not activated, and so is not emitting light, it can itself be seen, albeit only dimly, by reflected light – by light passing into the display from the ambient surroundings and then being reflected back out off the various

display components. This is aggravated by the fact that the material "surrounding" the display's phosphor shapes, namely the insulating layer (usually a ceramic) is of a different colour, and a different reflectivity, to that of the phosphor layer, so emphasising the visibility of the phosphor shapes even when unactivated.

[0018] The present invention suggests a simple solution to this, which is to modify - or apparently to modify - the colour/reflectivity of one or other (or, indeed, both) of the phosphor and the surrounding insulator material so as to "match" that of the other, and thus cause the phosphor and insulator material to blend with, and so be less distinguishable from, each other.

[0019] In one aspect, therefore, this invention provides an electroluminescent display of the type wherein a layer of electroluminescent material is sandwiched between but spaced from two electrode layers, and the electroluminescent material is composed of a plurality of separate areas each matching in shape and size the image which the relevant portion of the display is to show, each such area being surrounded by a layer of insulating material,

[0020] in which display the colour/reflectivity of one and/or other of the electroluminescent material and the surrounding insulator material is modified - or is apparently modified - so as to match that of the other.

[0021] The invention provides an electroluminescent display for some sort of device. This device can be of any shape and form, and for any purpose. A typical example of such a device is a hand-holdable controller - a remote control - for a radio, an audio cassette tape deck, a CD player, a television, a DVD player or a video recorder, and for such a use the device will normally have an oblong panel, perhaps 13x5cm (5x2in), on which are positioned a plurality of individual display elements appropriate to the device's purpose. Thus, for instance, for a tape deck the display elements might be ikons (or words, or the individual letters of words) that represent (amongst other possibilities) "play", "fast forward", "fast reverse", "record", and "stop".

[0022] The display of the invention is an electroluminescent display - that is, it is a display which uses electroluminescence to light up its several parts. More specifically, it is such a display utilising layers of a particulate electroluminescent material - a particulate phosphor - rather than continuous sheets or films of electroluminescent material. The particulate phosphor can be a light-emitting plastic (LEP) in particulate form, but most preferably it is an inorganic material; a typical inorganic particulate phosphor is zinc sulphide especially in the form of encapsulated particles (encapsulation provides substantially-increased stability and life). An especially convenient such zinc sulphide is that heat-curable material available under the name 7151j from Dupont, in a layer around 25 micrometer thick. Another such sulphide is 8164 High Bright Green, also from DuPont.

[0023] Unlike many electroluminescent displays known in the Art, the invention's display has, instead of a single large area of uniformly-activatable electroluminescent material forming a "back light" to the mask-defined characters or ikons to be displayed, separately-activatable individual areas each of which represents either a whole or a part of a character or ikon to be displayed. As a result, the display appears much sharper, crisper and "cleaner" than the conventional back-panel versions.

[0024] In this display each character or ikon can be whole and complete in itself – an individual number or letter (of the alphabet), or an ikon (or symbol, pictogram, cartouche or glyph) representing some desired effect (such as the right-pointing single chevron commonly employed to mean "play", or the similar double chevron meaning "fast forward"). However, in addition – or as an alternative – the individual areas can form small parts of a larger region which itself has some meaning or message. Thus, the small individual areas can be grouped into sets of related character-defining segments each group of which can, by the activation of the appropriate segments, define any character there to be displayed. A typical group is the standard seven-segment group commonly employed in modern electrical and electronic displays; by suitably choosing which of the segments is switched on, so the group can be made to display any Arabic numeral or Roman-alphabet character (other numbering or alphabet systems may need groups with more segments). The groups themselves can of course be disposed in an array; by manipulating each of the portions of the array so there may be presented, for example, a complete textual message.

[0025] Each activatable area comprises a thin (around 25 micrometre) layer of phosphor having on either side – adjacent each face of the layer – the (front or rear) electrode which is used to provide the voltage across the layer to switch it into its electroluminescent state. More specifically, in the first aspect of the invention – that aspect using shaped phosphor areas – that back electrode and also the electroluminescent material are each composed of a plurality of separate areas each matching in shape and size the image which the relevant portion of the display is to show. The thus-shaped back electrode is accordingly patterned, to form an array of separate appropriate tightly-defined outline shapes at the resolution of the information or information segments to be displayed, and each shape of this array is addressable (supplied with the driving voltage) independently of all the others.

[0026] In addition, the electroluminescent layer – the phosphor – is itself patterned with an appropriate array of tightly-defined outline shapes at the resolution of the information or information segments to be displayed.

[0027] As in the Art, the phosphor layer is covered with an insulating layer, usually of ceramic material. A typical such material is DuPont's heat-curable 7153e, or their UV-curable 5018 in a layer around 10 to 15 micrometre thick. The back electrodes are

then formed on this insulating layer, usually utilising a silver paste such as Norcote's UV-curable ELG110 to lay down a relatively thin layer - around 20 micrometre - where required.

[0028] The rear face of the display may then be protected with a thin - 15 micrometre - ceramic insulating layer (typically using DuPont's 5018, as above, though another possibility is Coates' UV600G).

[0029] By the shaped electrode/phosphor arrangement - both the back electrode and also the phosphor itself being composed of a plurality of separate areas each matching the image to be shown - so there is formed a display wherein, at least in principle, there can, in use be seen only the desired images, without any sign of "tails" caused by the electrodes' lead tracks. However, in practice it may be that the two arrays of shapes - in the chosen electrode and in the phosphor - are not perfectly aligned, with the result that some very short portion of an electrode's lead track may in fact overlap, and so activate, the corresponding phosphor shape. This out-of-registration problem can satisfactorily be dealt with in a number of ways. One - as already proposed - is to space the lead tracks further from the phosphor than their electrodes, so that the tracks necessarily have a less "activating" effect. If the spacing is sufficient then the activation of the phosphor by the tracks will be insignificant compared to that of the electrodes, and so will not be a distraction. Thus, if the chosen electrode array is the back electrodes, they are first formed without tracks, the spaces in between are then coated with an additional layer of an insulating material (typically a ceramic such as that already used between the back electrodes and the phosphor), and then the tracks are formed (with the same sort of silver paste) over the top of the insulating layer, so that the tracks are spaced further from the phosphor than the back electrodes, and thus their effect is suppressed.

[0030] The various layers of material from which the display of the invention is constructed can be formed by the usual screen printing methods, utilising the various techniques and paste-like materials generally known for that purpose, and no more need be said about that here.

[0031] Finally, in addition, the substrate may be overlaid with an exterior protective film, which can if appropriate be coloured or bear legends of one sort or another.

[0032] In the improved display of the invention the colour/reflectivity of one or other (or both) of the electroluminescent material - the phosphor - and the surrounding dielectric material (the ceramic/insulator) is modified so as to match - or appear to match - that of the other. This can be achieved in a number of distinct ways.

[0033] Firstly, the colour/reflectivity of the insulator material can be changed to match that of the phosphor. Thus, the insulator material to be used can be blended

with suitable colouring materials – inks or dyes – to give a colour match to the "off" (unactivated) state of the phosphor, so that when the coloured insulator material is then deposited everywhere the phosphor is not – that is, around the phosphor – there is presented the impression of a continuous layer when the combination is viewed through the transparent electrode.

[0034] The commonly-employed phosphors – for instance, the particular zinc sulphide referred to above – tend in their cured but "off" state to be an off-white or cream colour, while the ceramic-like insulator materials that surround the phosphor, such as those referred to hereinbefore, tend in their cured state to be white but to appear (at least, when viewed through an ITO-coated substrate) to be beige. The colour of such an insulator can be modified to be more like that of the phosphor by incorporating into the insulator suitable amounts of an appropriate solvent-based dye selected from Dylon's "Multipurpose" range – with the same specific phosphor and insulator mentioned above, the colour of the phosphor can be modified to be more like that of the insulator by incorporating into the phosphor suitable amounts of Dylon's "reindeer beige".

[0035] Secondly, there can be done what is effectively the opposite – the colour/reflectivity of the phosphor material can be changed to match that of the insulator. Thus, the phosphor material to be used can be blended with suitable colouring materials – inks – to give a colour match to the insulator material, so that when the insulator material is then deposited everywhere the phosphor is not – that is, around the phosphor – there is again presented the impression of a continuous layer when the combination is viewed through the transparent electrode.

[0036] With the same specific phosphor and insulator mentioned above, the colour of the phosphor can be modified to be more like that of the insulator by incorporating into the phosphor suitable amounts of an appropriate ink – in this case a white such as Sericol's Colorstar CS CS021.

[0037] Thirdly, the colour/reflectivity of each of the phosphor material and the insulating material can be modified so as more closely to match each other. Thus, the phosphor material to be used can be blended with a material of one suitable colour while the insulating material can also be blended with a material of a suitable colour – possibly a different colour, but most likely a different intensity of the same colour – so that when the insulator material is then deposited everywhere the phosphor is not – that is, around the phosphor (and, indeed, over the back of the phosphor) – there is again presented the impression of a continuous layer when the combination is viewed through the transparent electrode.

[0038] Obviously, care should be taken that the dye (or other colouring material) chosen (for whichever component), and the amount of it that is used, does not

deleteriously affect the required properties of the component – specifically the dielectric constant of the insulating material and the light-emitting capabilities of the phosphor.

[0039] A fourth possible way of achieving the desired colour/reflectivity matching of phosphor and insulator is to form between the substrate and the insulator layer an additional layer of suitably-coloured material so as effectively to mask the insulator layer from view, so again there is presented the impression of a continuous layer when the combination is viewed through the transparent electrode.

[0040] With the same specific phosphor mentioned above, the required insulator-masking layer can be formed using an ink such as Sericol's Colorstar(which has a matching white colour).

[0041] A fifth way of attaining the desired reduction in colour/reflectivity mismatch between the "off" phosphor and the insulator/dielectric material is to provide the display with a front filter/absorber layer – an overlay – of suitably-coloured transparent material so as appropriately to modify the manner in which external light entering the display from the ambient surroundings is transmitted thereinto and then reflected back. This filter layer, the use of which apparently modifies the colour/reflectivity of one or other of the electroluminescent/phosphor material and the surrounding insulator material so as to match that of the other, either can be a part of the substrate itself or, and preferably, it can be an additional layer formed on the substrate (and conveniently on the outside, front, surface).

[0042] This use of a coloured filter layer may be applied in addition to the colouring of the phosphor and/or insulating layer; indeed, such a combination of coloured phosphor and coloured filter is the preferred choice (the actual colours and intensities employed being carefully matched one to the other), with the use of a coloured insulator as well being most preferred, as described in more detail below.

[0043] The filter layer appropriately modifies how external light entering the display is then reflected back from the several interfaces – typically ambient air/filter, filter/substrate, substrate/phosphor and substrate/insulator. In this particular case what is required is that the light reflected off the very front of the display – the front of the filter – should be very much greater than the light reflected off any of the "internal" interfaces, and that the light reflected from the substrate/phosphor interface should match in colour and hue the light reflected from the substrate/insulator interface. And when the display – the phosphor – is "on" (activated), the output from the phosphor should be significantly greater than any reflected light (and especially that off the filter at the very front).

[0044] Although the filter can be positioned to be (or not to be) only at places in register with various individual images to be displayed, it can alternatively, and perhaps with advantage, cover the entire surface of the display.

[0045] It will be seen that, using such a filter, emitted light from the phosphor makes one pass through the filter while reflected light from the ambient surroundings must make two passes through the filter, and so the resultant visibility of any pattern of phosphor is, in the "off" state, reduced by the ratio of the absorbency of the filter. Of course, the overall brightness of the display is also reduced, but the ratio between the "on" state emissions and any of the various "off" state reflection levels is enhanced.

[0046] This effect can be further exploited if the reflectance spectrum of the filter is shifted in wavelength compared to the transmittance spectrum of the filter, so that the colour/hue of the emitted light from the phosphor is not the same as that of the reflected light from the very front - the filter - surface of the display. While this does not provide an improvement in light intensity terms nevertheless it improves visibility through chrominance contrast.

[0047] A suitable material colour for such a filter, providing the desired effect, is that deep blue provided by Ultramark under the designation 575/T134402.

[0048] As indicated, it is particularly preferred to colour all three components - the phosphor, the insulating layer, and the filter. Most conveniently all three colours are much the same but of different intensity - shades of blue, for example, or shades of grey - and the colours are preferably darker - more intense - the higher the intrinsic reflectivity of the component. For example, using the materials specifically identified above, the phosphor is both whiter and more reflective than the insulating layer, and so may need to be coloured darker (though, with such thin layers as these, it is likely that if the phosphor and the insulating layer are both coloured much the same, the former, upon which the latter is fabricated, will appear darker when viewed with the latter behind it. In this case, then, the coloured phosphor and insulating layer "match" each other not in the sense that when viewed directly they blend until the boundary between disappears but that when viewed through the applied filter layer they then appear to match, blending in the desired way.

[0049] Mathematically, the effects observed can be described generally by the following expressions:

[0050] In the "off" state there apply the following functions:

[0051] a) Dielectric

[0052]  $RJ[R_1, G_1, B_1] \times TJ[R_2, G_2, B_2] \Rightarrow I_0[R_3, G_3, B_3]$

- [0053] b) Dyed phosphor
- [0054]  $RJ[R_4, G_4, B_4] \times TJ[R_2, G_2, B_2] \Rightarrow I_0J[R_5, G_5, B_5]$
- [0055] so the eye perceives little or no "off" state clutter. In general, the hue of the incident light is irrelevant; it just changes the magnitude of  $I_0$ .
- [0056] In the "on" state:
- [0057] a) Dielectric
- [0058]  $RJ[R_1, G_1, B_1] \times TJ[R_2, G_2, B_2] \Rightarrow I_0J[R_3, G_3, B_3]$
- [0059] b) Dyed phosphor
- [0060]  $I_1J[R_6, G_6, B_6] \times TJ[R_2, G_2, B_2] \Rightarrow I_3J[R_7, G_7, B_7]$
- [0061] where  $I_3 \gg I_0$
- [0062] and
- [0063]  $R_2, R_7$  are small, and  $G_7B_7 > B_3$ .
- [0064] The described fifth way of attaining the desired reduction in colour/reflectivity mismatch between the "off" phosphor and the insulator/dielectric material is, as just discussed, to provide the display with a front filter/absorber layer – an overlay – of suitably-coloured transparent material so as appropriately to modify the manner in which external light entering the display from the ambient surroundings is transmitted thereinto and then reflected back. And so far this has been described in more detail in connection with the use of all three components having much the same colour (blue, specifically). However, it is perhaps surprisingly possible to achieve a similar effect in another, albeit related manner, which is to provide the front filter with a transparency colour that matches the light emitted by the display's lightable areas when they are "on" (for most of the preferred electroluminescent materials this is a bright green-white) but then to arrange that the phosphor and the insulating/dielectric material is coloured to have the complementary colour to this filter transmission colour.
- [0065] As a result, in the each area's "off" state the light reflected from the display – from each area and from the surrounding dielectric – is a mismatch to the transmission characteristics of the filter, and so is absorbed, with the result that the display appears uniformly very dark, even black; and the individual phosphor areas cannot be distinguished. In the "on" state, of course, the emitted light matches the filter's transmissivity, and provides a bright high-contrast display.

- [0066] Mathematically, the effects observed can be described generally by the following expressions:
- [0067] In the "off" state there apply the following functions:
- [0068] a) Dielectric
- [0069]  $RJ[R_1, G_1, B_1] \times TJ[R_2, G_2, B_2] \Rightarrow I_0[J[R_3, G_3, B_3]$
- [0070] b) Dyed phosphor
- [0071]  $RJ[R_4, G_4, B_4] \times TJ[R_2, G_2, B_2] \Rightarrow I_0[J[R_5, G_5, B_5]$
- [0072] where, for the case of a blue-emitting phosphor and a blue filter,
- [0073]  $B_1 - B_4 \ll R_1, R_4, G_1, G_4$ , and  $I_0$  is much less than the intensity of the general ambient light.
- [0074] In the "on" state:
- [0075] b) Dyed phosphor
- [0076]  $I_1[J[R_5, G_5, B_5] \times TJ[R_2, G_2, B_2] \Rightarrow I_2[J[R_6, G_6, B_6]$
- [0077] where  $I_2$  is approximately  $I_1$ , and  $>> I_0$ ,
- [0078] and
- [0079]  $B_6 >> R_6, G_6$ .
- [0080] Various embodiments of the invention are now described, though by way of illustration only, with reference to the accompanying diagrammatic Drawings in which:
- [0081] Figure 1 shows in section a portion of a simplified Prior Art electroluminescent display;
- [0082] Figure 2 shows in section a portion of an improved, patterned back electrode, version of the Figure 1 simplified Prior Art display;
- [0083] Figure 3 shows in section a portion of a further improved, spaced track, version of the Figure 2 simplified Prior Art display;
- [0084] Figure 4 shows in section a portion of a simplified display similar to that of Figure 2 but further improved - having a patterned phosphor layer;

- [0085] Figure 5 shows in section a portion of an improved simplified display similar to that of Figure 4 but further improved in the spaced-track manner shown in Figure 3;
- [0086] Figure 6 shows in section a portion of an improved simplified display similar to that of Figure 5 but yet further improved by "colouring" the ceramic insulator layer in accordance with the invention;
- [0087] Figure 7 shows in section a portion of an improved simplified display similar to that of Figure 5 but alternatively yet further improved by "colouring" the phosphor layer in accordance with the invention;
- [0088] Figure 8 shows in section a portion of an improved simplified display similar to that of Figure 5 but alternatively yet further improved by providing an additional internal layer colour-matching the phosphor layer in accordance with the invention;
- [0089] Figure 9 shows in section a portion of an improved simplified display similar to that of Figure 5 but alternatively yet further improved by using an external "colouring" layer in accordance with the invention; and
- [0090] Figure 10 shows in section a portion of an improved simplified display similar to that of Figure 9 but yet further improved by using, in addition to an external "colouring" layer, coloured phosphor and insulating material layers as well, in accordance with the invention.
- [0091] Figure 1 shows in section a portion of a simplified Prior Art electroluminescent display. The display is built up on a transparent protective substrate (11) carrying the thin front electrode (12) on which is formed the thicker electroluminescent material (phosphor) layer (13). This phosphor is a granular, particulate, material (AS 14) held within a binding matrix (15); the layer itself, however, is here shown as a continuous layer, extending over the entire area of the display.
- [0092] Behind the phosphor layer 13 – on top, as viewed – is a thick layer of an insulating ceramic layer (16), and on that has been formed the back electrode (17). This back electrode is a continuous one, extending, like the phosphor layer 13 over the entire area of the display.
- [0093] In use an opaque mask (18) is positioned in front of the display – below it, as viewed. By the shaped apertures (as 19) this mask defines the "images" that the display is to show, the light ( $I_e$ ) emitted by the phosphor being allowed through each aperture 19 but being blocked everywhere else.
- [0094] Figure 2 shows in section a similar display portion, with substrate 11, transparent front electrode 12, continuous phosphor layer 13, and ceramic insulator layer 14, but has an image-defining back electrode made up of a number of shaped

areas (as 21: only one is here shown) each addressable via thin and narrow lead tracks (as 22). Using a shaped, patterned back electrode 21 means notionally that only those areas (as A) of phosphor directly between the individual shapes 21 and the front electrode 11 are activated, providing illumination  $i_e$ . In practice, however, the individual lead tracks 22 also act as back electrodes, so that some small amount of illumination  $i_e$  is also output from the phosphor layer under them, making the display seem confusing. This problem can be at least partly dealt with in the manner shown in Figure 3, which shows a "spaced-track" version of the Figure 2 display. As can be seen from Figure 3 the shaped areas 21 of the back electrode have been surrounded by a thick layer (31) of insulating material, and then the lead tracks 32 to the electrode areas 21 have been formed on top of that. It will be evident that the tracks 32 are spaced considerably further from the phosphor layer 13 in the Figure 3 embodiment than are the similar tracks 22 in the Figure 2 embodiment, so that the effect the tracks 32 have is concomitantly smaller, and thus the amount of light ( $i_e$ ) that they cause to be emitted is also concomitantly smaller, possibly even to the extent of being negligible.

[0095] An improved arrangement for avoiding lead track effects is shown in Figure 4. This shows in section a portion of a simplified display similar to that of Figure 2 but further improved by being made with a patterned phosphor layer made up of separate individual shapes (43) of phosphor material (43). As will be readily apparent, upon activation the emitted light can only come from the shaped phosphor portions, so there can – in principle – be none emitted because of the field generated by the lead tracks 22. However, in practice it may be that the phosphor and back electrode layers 43 and 21 are not exactly in register with each other, so that some short track portion might overlay a part of the relevant phosphor shape 43, and therefore to minimize any resulting effect of the tracks they are best constructed in the "raised" manner shown in Figure 3 – and this is shown in Figure 5.

[0096] The present invention provides an electroluminescent display in which the colour/reflectivity of one or other of the electroluminescent material and the surrounding insulator material is modified so as to match that of the other. This is shown in Figures 6, 7 and 8.

[0097] In Figure 6 is shown one such modified version, wherein the ceramic insulator layer (84) has been coloured to match the colour of the phosphor 43. Figure 7 shows the case where the phosphor (93) has been coloured to match the ceramic insulator layer 14 and Figure 8 shows the case where an ink layer (101) has been provided around the shaped area phosphor 43 on the transparent electrode 12 with the ceramic insulator layer 14 over both. The ink layer 101 is coloured to match the phosphor 43.

[0098] In Figure 9 there is shown a slightly different way of reducing the apparent contrast between the shaped area phosphor 43. Over the entire front surface of the

substrate 11 there has been formed a coloured filter layer (111). The filter layer modifies how external light ( $I_0$ ) entering the display is then reflected back from the several interfaces – filter/substrate 111/11, substrate/phosphor 11/43 and substrate/insulator 11/14 (the very thin transparent electrode 12 is here ignored) – such that the light ( $I_1$ ) reflected off the very front of the display – the front of the filter – is very much greater than the light  $I_2$ ,  $I_3$  reflected off any of the "internal" interfaces, and that the light  $I_2$  reflected from the substrate/phosphor interface should match in colour and hue the light  $I_3$  reflected from the substrate/insulator interface. And when the display – the phosphor 43 – is "on" (activated), the light ( $I_4$ ) output from the phosphor is significantly greater than any reflected light (and especially that,  $I_1$ , off the filter 111 at the very front).

[0099] As observed hereinbefore, it will be seen that emitted light  $I_4$  from the phosphor 43 makes one pass through the filter 111 while reflected light  $I_2$ ,  $I_3$  originating from the ambient surroundings must make two passes through the filter, and so the resultant visibility of any pattern of phosphor 42 is, in the "off" state, reduced by the ratio of the absorbency of the filter. The result is that there is presented the impression of a continuous layer when the combination is viewed.

[0100] And if the reflectance spectrum of the filter 111 is shifted in wavelength compared to the filter's transmittance spectrum, so that the colour/hue of the viewed emitted light  $I_4$  from the phosphor 43 is not the same as that of the reflected light  $I_1$  from the very front – the filter – surface of the display, then there is achieved an improvement in visibility through chrominance contrast.

[0101] Finally, Figure 10 shows in section a portion of an improved simplified display similar to that of Figure 9 but yet further improved by using, as well as an external "colouring" layer, coloured phosphor and insulating material layers as well.

[0102] The preferred insulating material/dielectric – Dupont 7153 – is a broadband reflector with negligible colour hue. Assuming white light is shone on it, it therefore reflects equal amounts of red, green and blue, and when viewed through a blue filter all that can be seen is the blue coloration. A phosphor layer – Dupont 8164, for instance – dyed with a blue such as Stamps Direct's Ink X2 Blue (a commercial version of the blue known generally as "Solvent Blue"), giving it a reflectance spectrum that matches the transmission spectrum of the blue filter (a PVC-based material from Ultramark; 575T134402), also can be seen through the filter as blue. These two observed blues match: the phosphor cannot easily be picked out from the surrounding dielectric.

[0103] In this particular blue case it has been found that colouring the dielectric a very pale blue (the same blue that, in a darker form, is used in the filter) and the phosphor a slightly darker shade of the same blue (particularly as the layer of dielectric behind the phosphor makes the phosphor appear to be even darker), improves the